

Table 11. Test conditions for tests conducted in a manufactured home

Test	Ignition	Fuel Package	Fire Location	Comments
SDC01	Smoldering	Chair	Living Area	
SDC02	Flaming	Chair	Living Area	
SDC03	Smoldering	Mattress	Bedroom	Ignition failure
SDC04	Smoldering	Mattress	Bedroom	
SDC05	Flaming	Mattress	Bedroom	
SDC06	Smoldering	Mattress	Bedroom	
SDC07	Flaming	Mattress	Bedroom	
SDC08	Smoldering	Mattress	Bedroom	
SDC09	Flaming	Mattress	Bedroom	
SDC10	Flaming	Chair	Living Area	
SDC11	Smoldering	Chair	Living Area	
SDC12	Heating	Cooking Oil	Kitchen Area	
SDC13	Heating	Cooking Oil	Kitchen Area	
SDC14	Smoldering	Mattress	Bedroom	Bedroom door closed
SDC15	Flaming	Chair	Living Area	
SDC30	Smoldering	Chair	Living Area	Ignition failure
SDC31	Smoldering	Chair	Living Area	
SDC32	Flaming	Chair	Living Area	Ignition failure
SDC33	Flaming	Chair	Living Area	
SDC34	Smoldering	Chair	Living Area	
SDC35	Flaming	Chair	Living Area	
SDC36	Flaming	Mattress	Bedroom	Bedroom door closed
SDC37	Smoldering	Mattress	Bedroom	
SDC38	Flaming	Mattress	Bedroom	
SDC39	Flaming	Mattress	Bedroom	
SDC40	Smoldering	Mattress	Bedroom	
SDC41	Heating	Cooking Oil	Kitchen Area	

Table 12. Test Conditions for tests conducted in a two-story home

Test	Ignition	Fuel Package	Fire Location	Comments
SDC20	Flaming	Mattress	Bedroom	Bedroom door closed
SDC21	Smoldering	Mattress	Bedroom	Alarms not reached
SDC22	Flaming	Mattress	Bedroom	Ignition failure
SDC23	Smoldering	Chair	Living Room	
SDC24	Heating	Cooking Oil	Kitchen	
SDC25	Flaming	Chair	Living Room	
SDC26	Flaming	Chair	Living Room	
SDC27	Smoldering	Chair	Living Room	Air-conditioning upstairs
SDC28	Flaming	Fully furnished room	Living Room	

5.2 Test Data

As an example of the analysis details, test SDC05 was chosen. This test was a flaming mattress test in a bedroom of the manufactured home. It was chosen as a single representative test, but does include all of the relevant test data. In addition for this test, all of the alarm types responded to the fire. Figures 100 through 121 present the data from test SDC05.

Mass loss of the burning mattress is shown in figure 100. Mass loss grows from shortly after ignition to a peak of approximately 150 g at the end of the test. Like all of the tests in the project, this test was terminated once untenable conditions had been reached in the path of egress from the home. A manually-operated water spray from copper tubing directed at the burning chair (see figure 94) at the end of the test quickly suppressed the fire resulting in a sharp drop in mass loss at the end of the test as the water collected in the pan supporting the mattress. The initiation of this manual suppression is noted in the figure as “Initiation of Suppression.”

Figures 101 to 107 show measured profiles of gas temperature from ceiling to floor in several locations throughout the home. In the ignition location (in a bedroom at one end of the manufactured home, noted as “Main Bedroom” for this report), temperatures reached 120 °C near the ceiling (20 mm from the ceiling) and 98 °C near face level (900 mm below ceiling or 1.5 m from the floor) at the end of the test. Further from the fire, peak temperatures were naturally lower, ranging from 87 °C just outside the main bedroom down to 42 °C in the bedroom farthest from the fire. In the closed bedroom, temperatures remain near ambient.

Table. 23. Average time to alarm (in seconds) for several smoke alarms and fire scenarios in a manufactured home

Every Level Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	131	73	77	138
Bedroom	96	61	186	121
Bedroom (Door Closed)	619	172	630	643
Smoldering				
Living Room	4615	4829	4605	4541
Bedroom	2622	3631	3471	2997
Cooking				
Kitchen	766	520	912	1172

Every Level + Bedrooms Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	125	60	68	138
Bedroom	78	37	186	121
Bedroom (Door Closed)	84	34	619	643
Smoldering				
Living Room	3856	4695	4304	4541
Bedroom	2179	3618	3471	2997
Cooking				
Kitchen	764	520	539	1172

Change from Every Level

Photo	Ion	Dual Ion/Photo	Aspirated
-5	-13	-10	--
-18	-25	--	--
-535	-138	-11	--
Smoldering			
-759	-134	-301	--
-443	-13	--	--
Cooking			
-3	--	-320	--

Every Room Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	92	28	77	n.a
Bedroom	78	37	104	n.a
Bedroom (Door Closed)	84	34	134	n.a
Smoldering				
Living Room	2552	4402	4304	n.a
Bedroom	2179	3618	3429	n.a
Cooking				
Kitchen	691	487	539	n.a

Change from Every Level + Bedrooms

Photo	Ion	Dual Ion/Photo	Aspirated
-22	-22	--	n.a.
--	--	-83	n.a.
--	--	-485	n.a.
Smoldering			
-1304	-293	--	n.a.
--	--	-42	n.a.
Cooking			
-73	-33	--	n.a.

Table 24. Average time to alarm (in seconds) for several smoke alarms and fire scenarios in a two-story home

Every Level Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	107	70	553	553
Bedroom	404	30	404	404
Bedroom (Door Closed)	186	164	3602	3602
Smoldering				
Living Room	1542	4824	1508	1424
Living w/AC	1366	4192	2030	2072
Cooking				
Kitchen	880	1554	898	858

Every Level + Bedrooms Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	107	70	553	553
Bedroom	98	30	82	404
Bedroom (Door Closed)	186	164	3602	3602
Smoldering				
Living Room	1542	4824	1508	1424
Living w/AC	1338	4192	2030	2072
Cooking				
Kitchen	880	1554	898	858

Every Room Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	107	70	307	330
Bedroom	98	30	82	404
Bedroom (Door Closed)	186	164	3602	3602
Smoldering				
Living Room	1542	4824	1508	1424
Living w/AC	1338	4192	2030	2072
Cooking				
Kitchen	880	1290	876	828

Table. 27. Available egress time (in seconds) for several different alarm technologies and fire scenarios in a manufactured home

Every Level Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	85	142	138	78
Bedroom	58	93	39	45
Bedroom (Door Closed)	451	898	958	427
Smoldering				
Living Room	172	-43	182	245
Bedroom	1364	102	344	716
Cooking				
Kitchen	575	821	899	170

Every Level + Bedrooms Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	90	155	138	78
Bedroom	76	118	39	45
Bedroom (Door Closed)	986	1036	980	427
Smoldering				
Living Room	930	91	483	245
Bedroom	1534	95	339	724
Cooking				
Kitchen	578	821	803	170

Change from Every Level

Photo	Ion	Dual Ion/Photo
5	13	--
18	25	--
535	138	22
Smoldering		
759	134	301
171	17	--
Cooking		
3	--	373

Every Room Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	123	188	138	n.a
Bedroom	76	118	50	n.a
Bedroom (Door Closed)	986	1036	936	n.a
Smoldering				
Living Room	2234	384	483	n.a
Bedroom	1534	95	284	n.a
Cooking				
Kitchen	651	855	803	n.a

Change from Every Level + Bedrooms

Photo	Ion	Dual Ion/Photo
33	32	--
--	--	11
--	--	485
Smoldering		
1304	293	--
--	--	--
Cooking		
73	33	--

n.a. – no additional alarm included of this type

Table 28. Available egress time (in seconds) for several different alarm technologies and fire scenarios in a two-story home

Every Level Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	108	152	-448	–
Living Room (Replicate)	134	172	-96	–
Living Room (Fully-Furnished)	144	172	–	–
Bedroom	–	374	–	–
Bedroom (Door Closed)	3416	3438	–	–
Smoldering				
Living Room	3298	16	3332	3416
Living Room (Air Conditioning)	2772	-54	2108	2066
Cooking				
Kitchen	952	278	934	974

Every Level + Bedrooms Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	108	152	-448	–
Living Room (Replicate)	134	172	-96	–
Living Room (Fully-Furnished)	144	172	–	–
Bedroom (Door Closed)	3416	3438	–	–
Smoldering				
Living Room	3298	16	3332	3416
Living Room (Air Conditioning)	2800	-54	2108	2066
Cooking				
Kitchen	952	278	934	974

Every Room Installation Criterion

Flaming	Photo	Ion	Dual Ion/Photo	Aspirated
Living Room	108	152	102	–
Living Room (Replicate)	134	172	96	–
Living Room (Fully-Furnished)	144	172	–	–
Bedroom (Door Closed)	3416	3438	–	–
Smoldering				
Living Room	3298	16	3332	n.a.
Living Room (Air Conditioning)	2800	-54	2108	n.a.
Cooking				
Kitchen	952	542	956	n.a.

n.a. – no additional alarm included of this type

compared to the performance of similar smoke alarms in the 1975 test series. Table 30 shows a comparison between the two test series.

These differences appear to be not so much because the alarms are activating more slowly, but rather because the tenability limits are being exceeded much faster. For flaming fires, alarm activation was somewhat shorter in the current tests than in the 1975 tests, and time to untenable conditions was dramatically faster in the current tests. This may be attributed partially to the different ISO tenability criteria compared to simpler limits in the 1975 study, and also due to significantly faster fire development observed in the upholstered furniture and mattresses used in these tests.

Table 31 shows a comparison of tenability criteria used in the two studies. For the temperature and smoke obscuration criteria, values used in the current study are similar or slightly higher than those used in the 1975 study. For CO concentration, the range for the FED-based model used in the current study includes the value used in the 1975 study, but is also quite a wide range, depending on duration of the fire. For nearly all tests, the temperature or smoke criteria was met prior to the CO criterion.

A comparison of the fire growth in the two tests can be seen by comparing the temperatures near the ceiling for the tests from the two studies. For this comparison, the time for the temperature near the ceiling to reach 65 °C was used as an indication of the

Table 30. Comparison of alarm times and times to untenable conditions for 1975 and current studies

		1975 Tests	Current Tests
Alarm Times	Flaming	146 ± 93	47 ± 35
	Smoldering	1931 ± 1103	2042 ± 876
Tenability Times	Flaming	1036 ± 374	175 ± 70
	Smoldering	4419 ± 1790	2076 ± 963

Table 31. Comparison of tenability criteria used in the 1975 and current studies

	1975 Study	Current Study
Temperature	$T \geq 66 \text{ }^\circ\text{C}$	$T \geq 88 \text{ }^\circ\text{C}^{\text{a}}$
Gas Concentration	$\text{CO} \geq 0.04 \text{ \%}$ volume fraction	$\text{CO} \geq 0.02 - 0.3^{\text{b}}$ % volume fraction
Smoke Obscuration	$\text{O.D.} \geq 0.23 \text{ m}^{-1}$	$\text{O.D.} \geq 0.25 \text{ m}^{-1}$

a – calculated value for flaming fires calculated from ISO TS 13571 equation for convected heat

b – range of average values calculated from ISO TS 13571 equation for asphyxiant gases with tenability times for flaming fires and smoldering fires

Table 32. Comparison of fire growth rates in the 1975 and current studies

		Time to 65 °C near burn room ceiling (s)	
		1975 Study	Current Study
Flaming		969 ± 527	131 ± 40
Smoldering		4893 ± 2236	4332 ± 1893